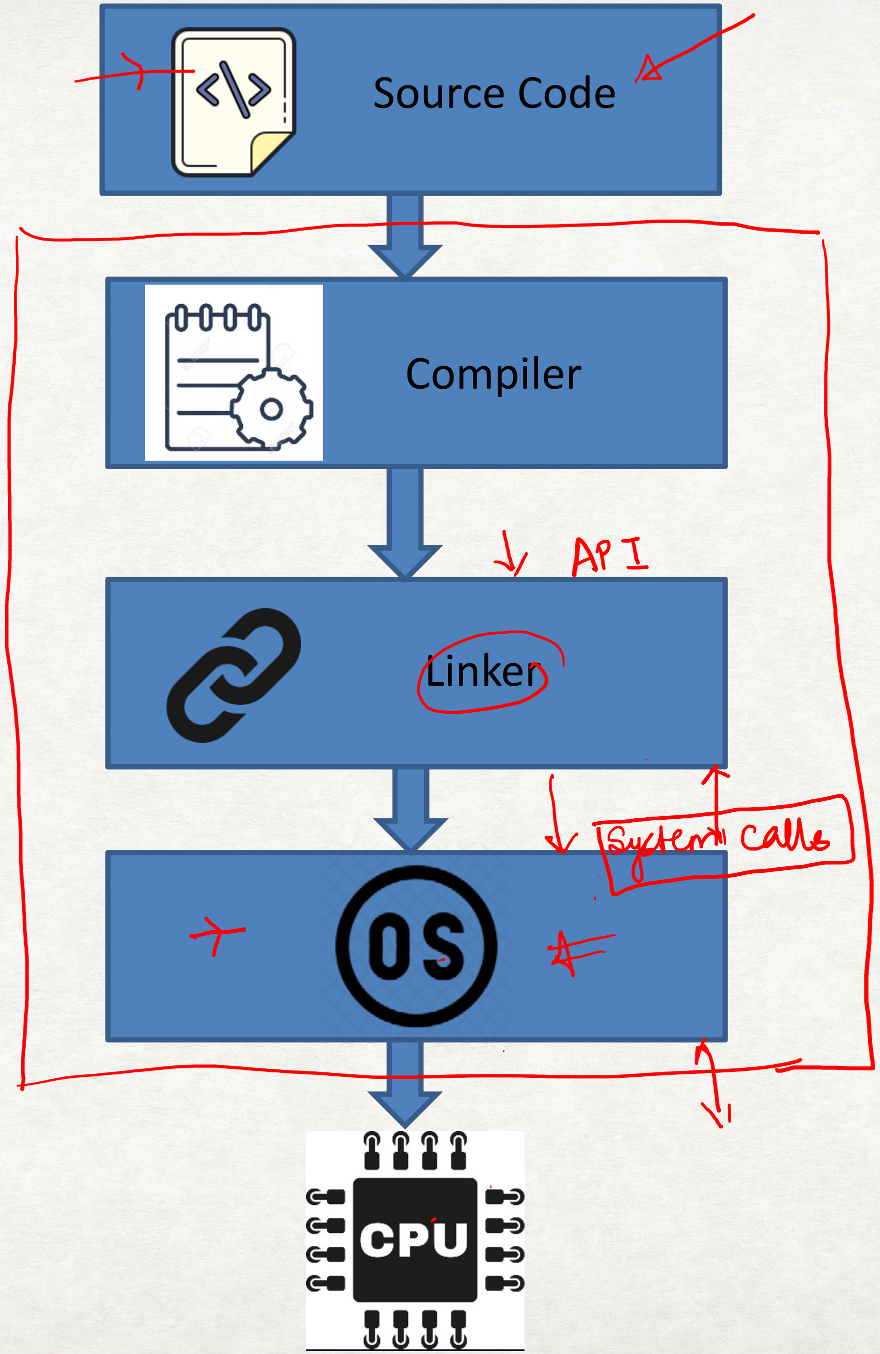
Networking III: Layering & Encapsulation

COMPSCI110

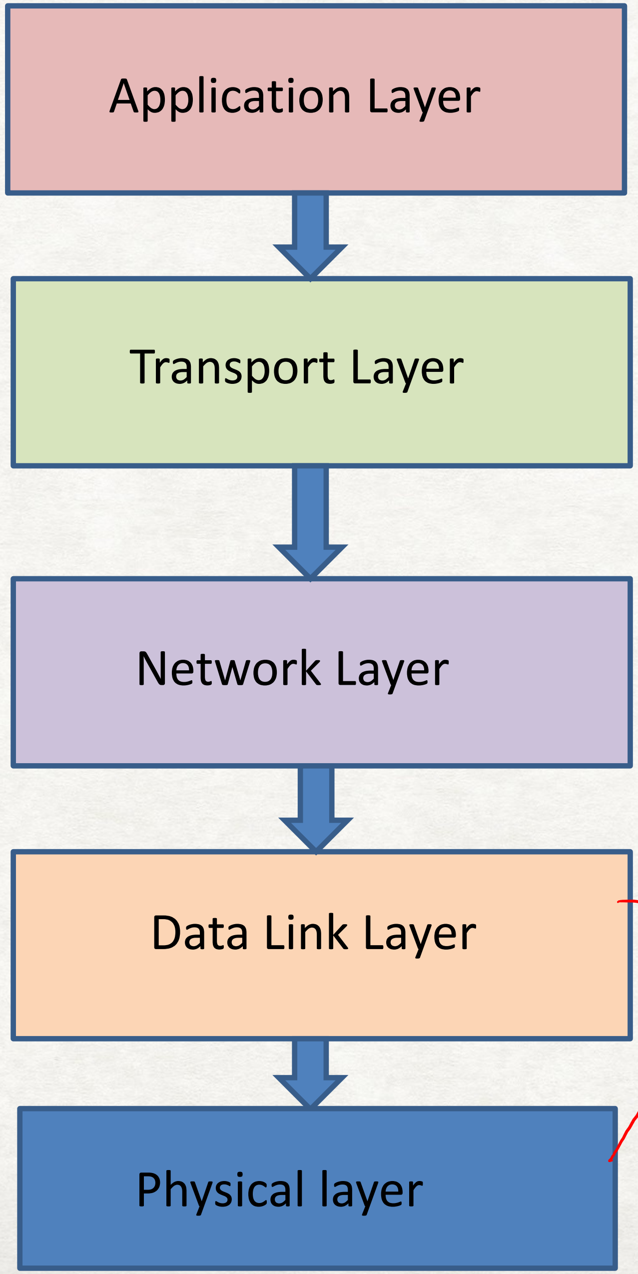
Layering in Software

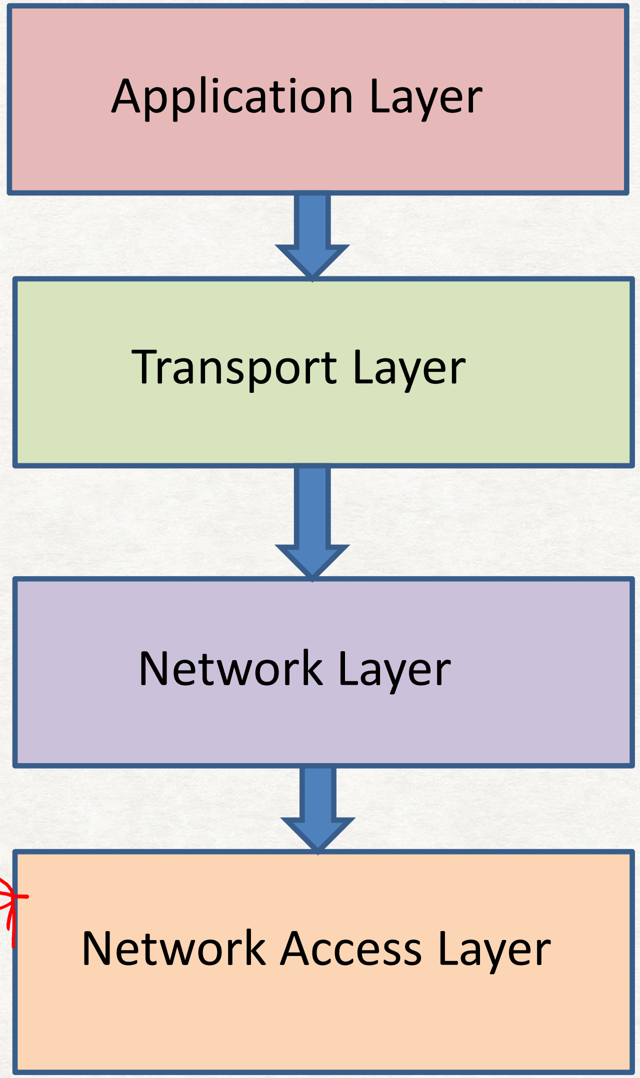
Advantages of Layering

1. Modularity
2. Reuse
3. Well defined service
4. Separation of Concerns
5. Maintenance & Improvement



Internet’s 5-Layer Model: TCP/IP Model

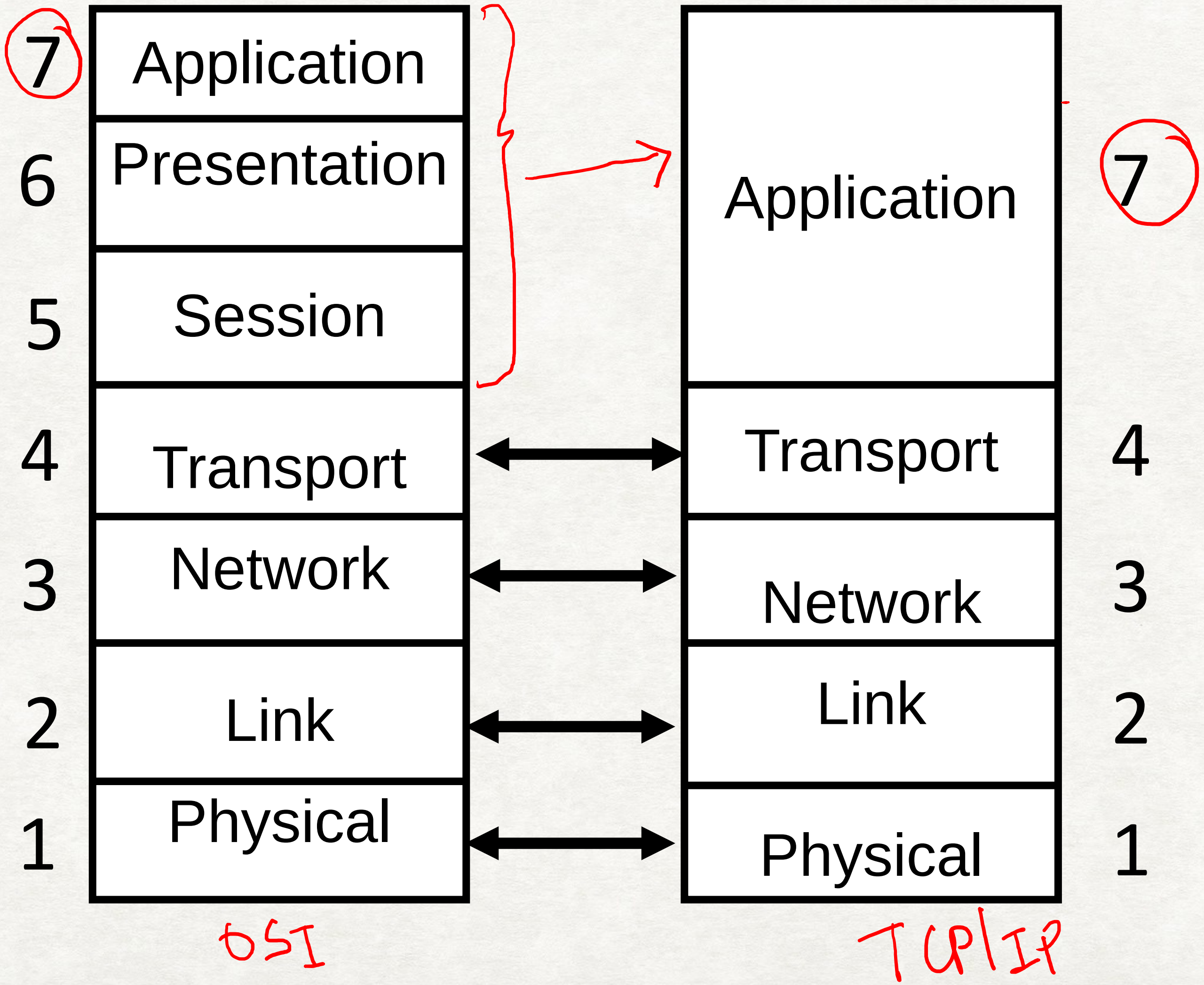




Older models often show only four layers, combining the physical and data link layers

TCP/IP vs OSI Layers

ISO/OSI



Internet's 5-Layer Model: TCP/IP Model

Protocol suite
stack

TCP/IP Protocol

Layer	Protocols
Application Layer	FTP, SMTP, HTTP…..
Transport Layer	TCP, UDP …..
Network Layer	IP
Data Link Layer	Ethernet, 802.11 (WiFi) , FDDI
Physical layer	Bits "on the wire" 1100011 - - - -

110001. - - -

What’s a protocol?

Human protocols:

- “what’s the time?”
- “I have a question”
- introductions

Rules for:

… specific messages sent

… specific actions taken when message received, or other events

Network protocols:

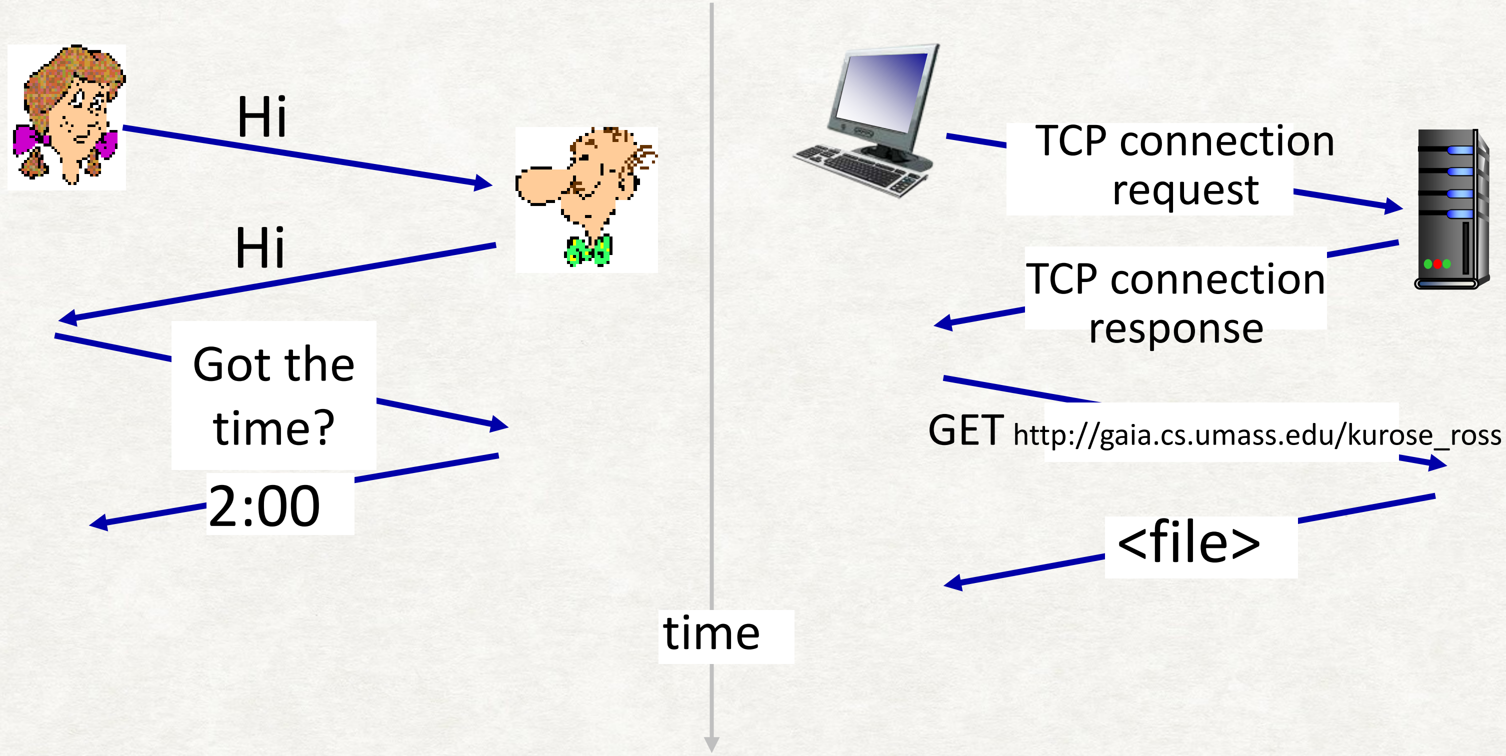
- computers (devices) rather than humans
- all communication activity in Internet governed by protocols

Protocols define the format, order of messages sent and received among network entities, and actions taken on message transmission, receipt

Reference : *Computer Networking: A Top Down Approach by Kurose & Ross*

What's a protocol?

A human protocol and a computer network protocol:



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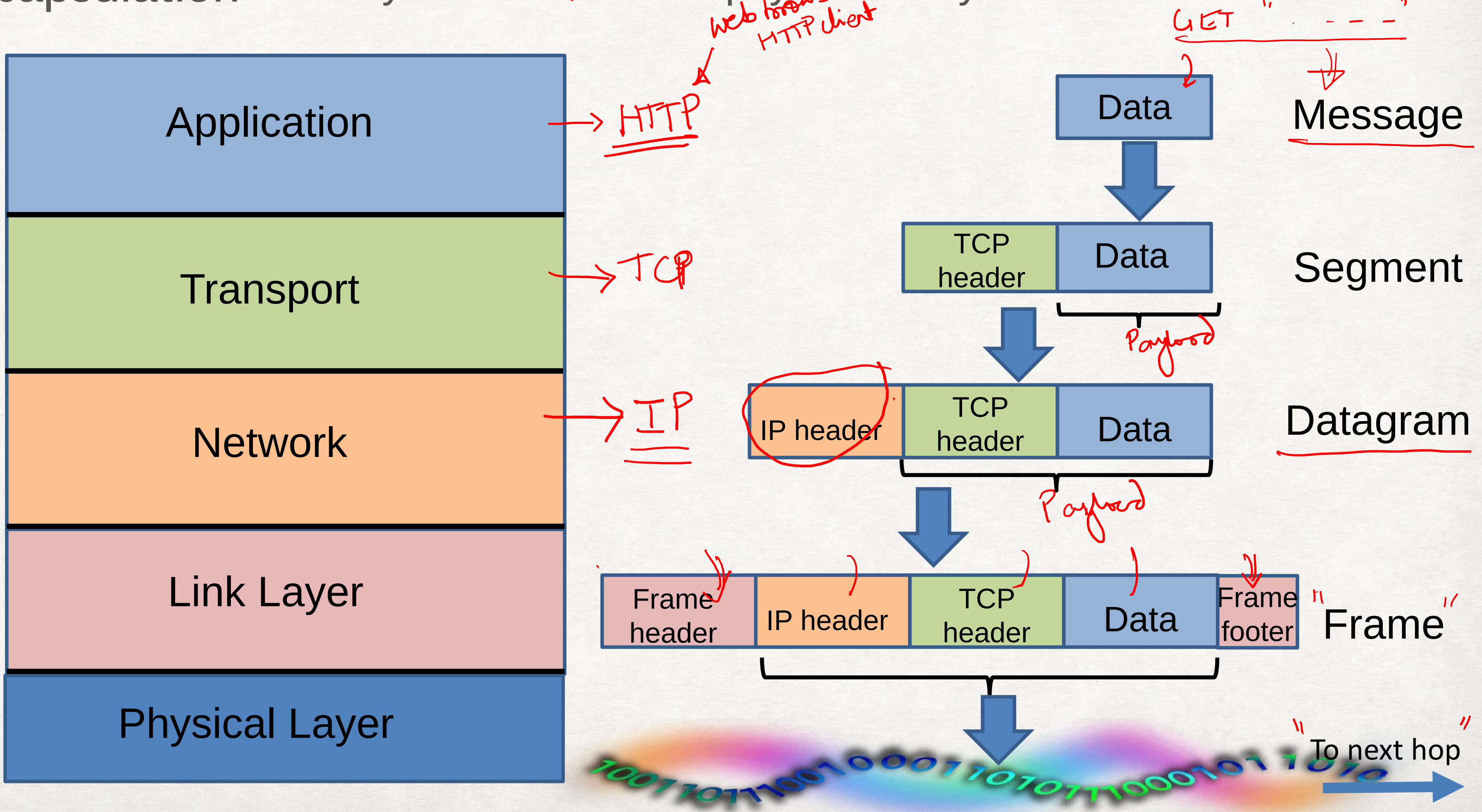
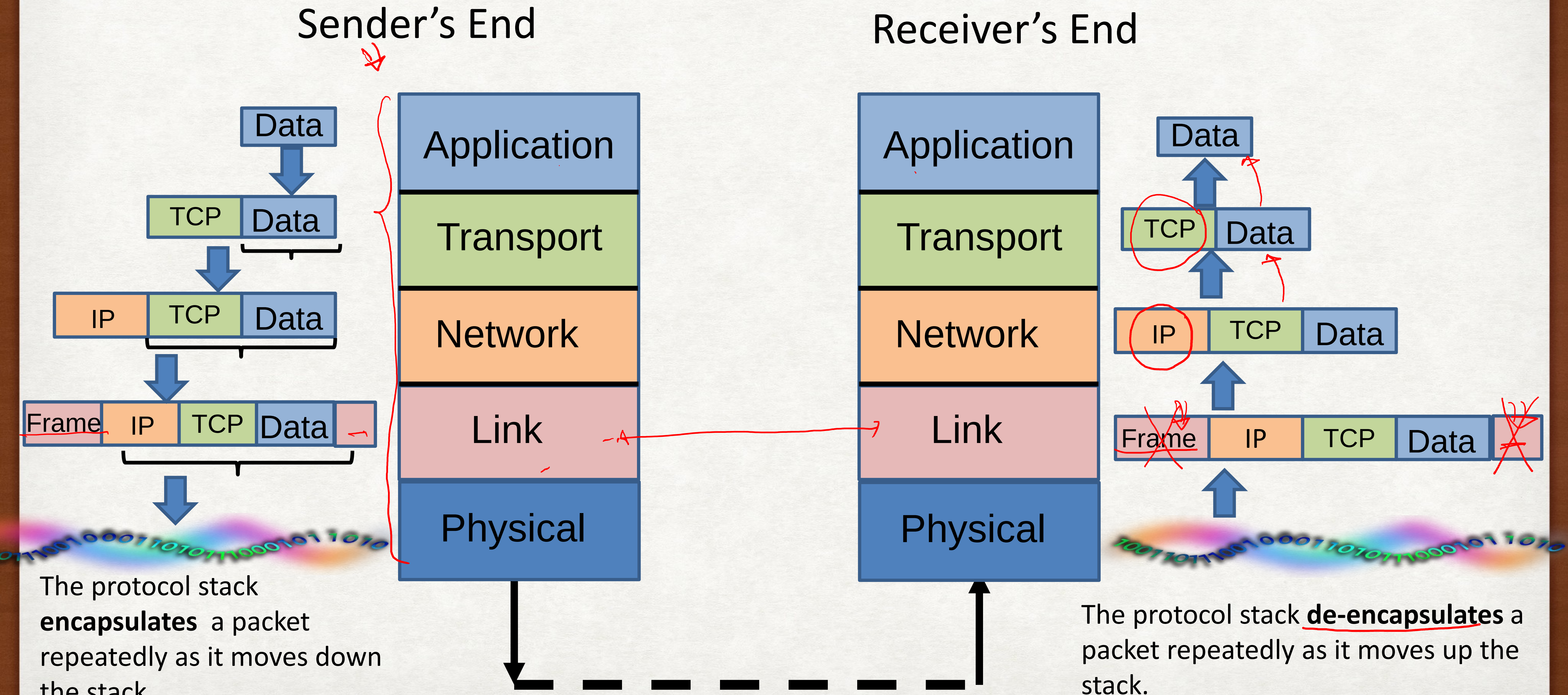
"Encapsulation"

"TCP/IP"

Layer N's ~~data is~~ the payload to layer N-1



At the receiver's end......



The protocol stack **encapsulates** a packet repeatedly as it moves down the stack.

The protocol stack **de-encapsulates** a packet repeatedly as it moves up the stack.

MTU & MSS

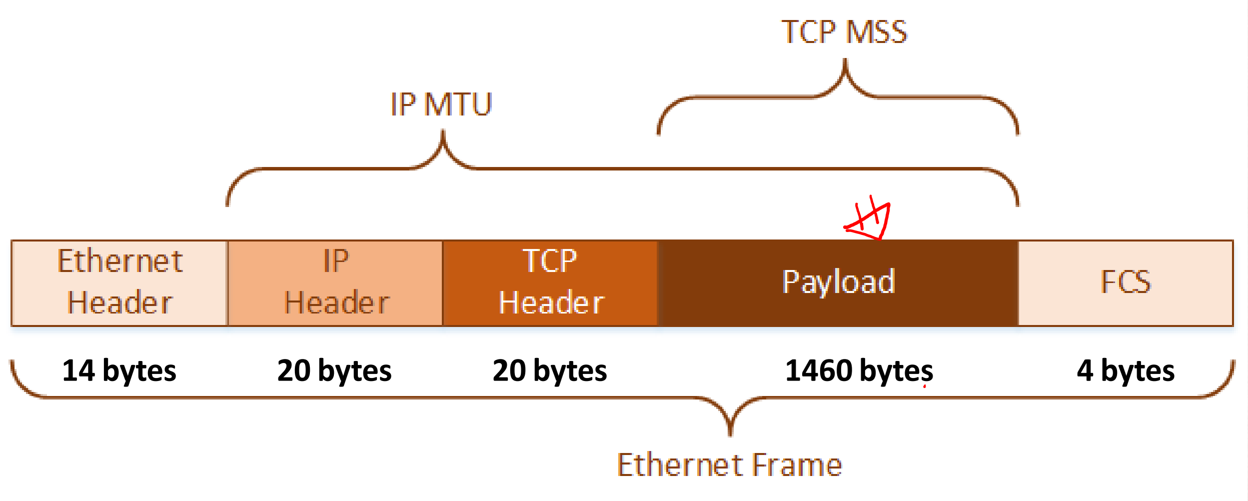
MTU (Maximum Transmission Unit)

- It is the **largest data packet** that can be transmitted across a network.
- It does NOT include the Ethernet headers required to transmit the packet on Ethernet.
- The common value of MTU on the Internet is **1500 bytes**.

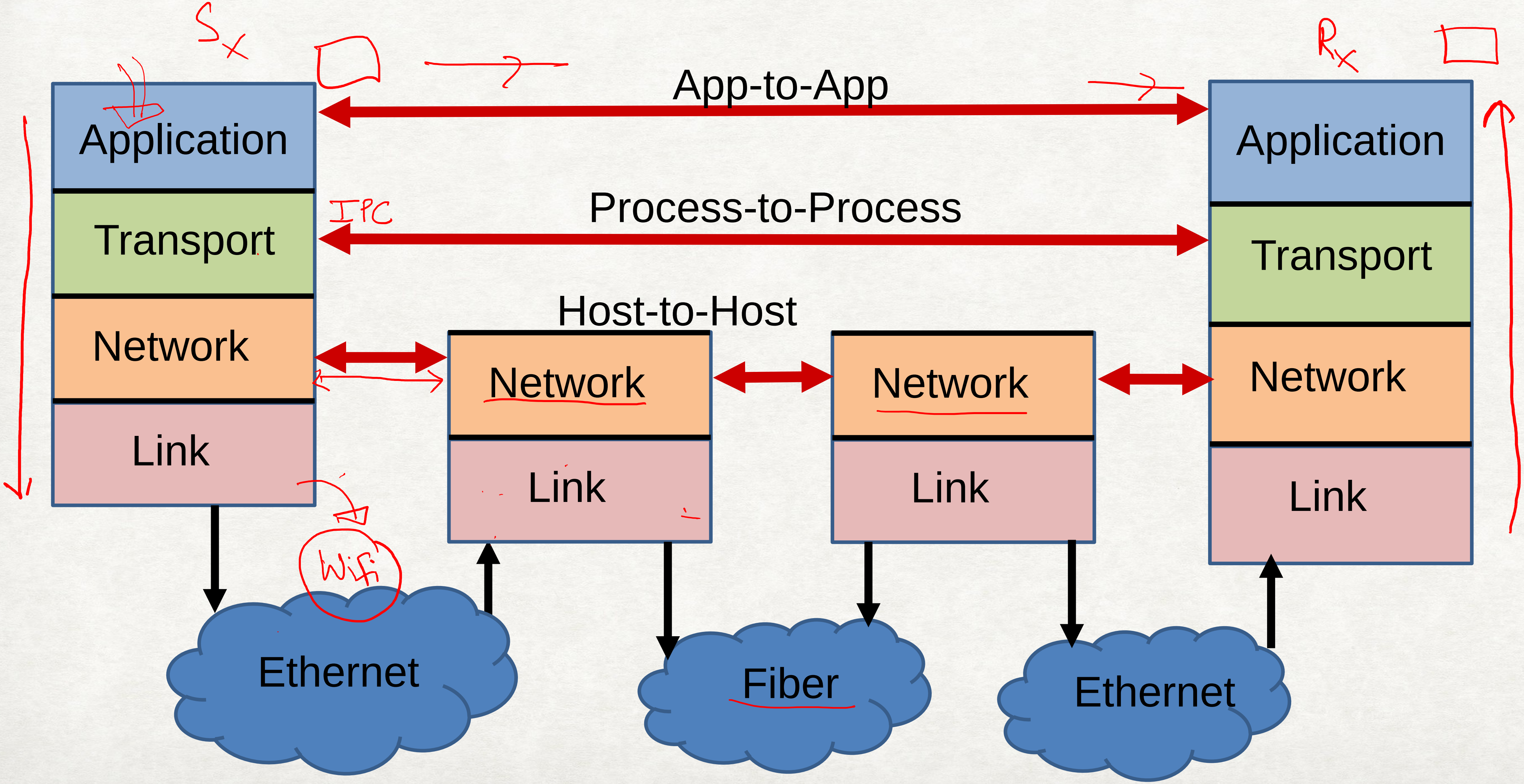
MSS (maximum segment size)

- MSS is only concerned with the size of the payload within each packet.
- It does NOT include the TCP header or the IP header.

MTU - (TCP header + IP header) = MSS



Benefits of Layering & Encapsulation in Networks



Application layer to Transport layer

Application
Transport
Network
Link
Physical

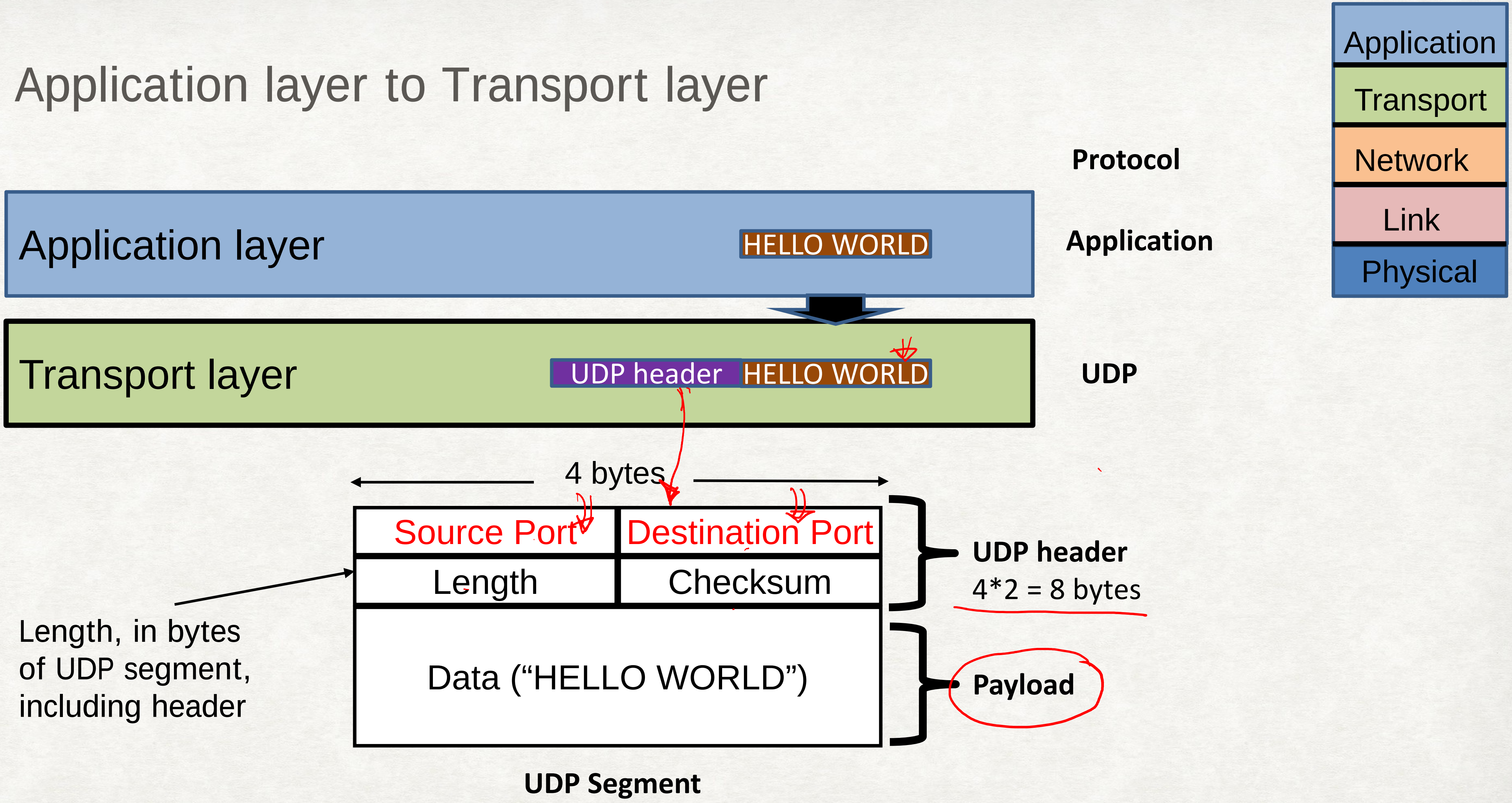
		Protocol
Application layer	HELLO WORLD	Application
Transport layer	TCP/UDP header HELLO WORLD	TCP/ UDP

Transmission Control Protocol (TCP)
reliable, in-order delivery

User Datagram Protocol (UDP)
unreliable, unordered delivery
No-frills extension of "best-effort" IP

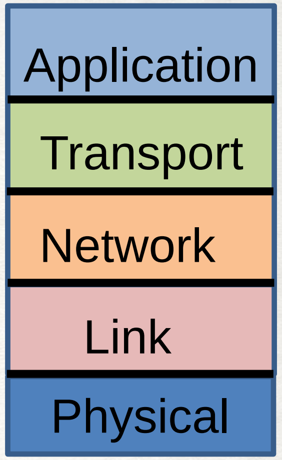
Online gaming
Video streaming
VoIP ← Zoom call
→ "Timing"

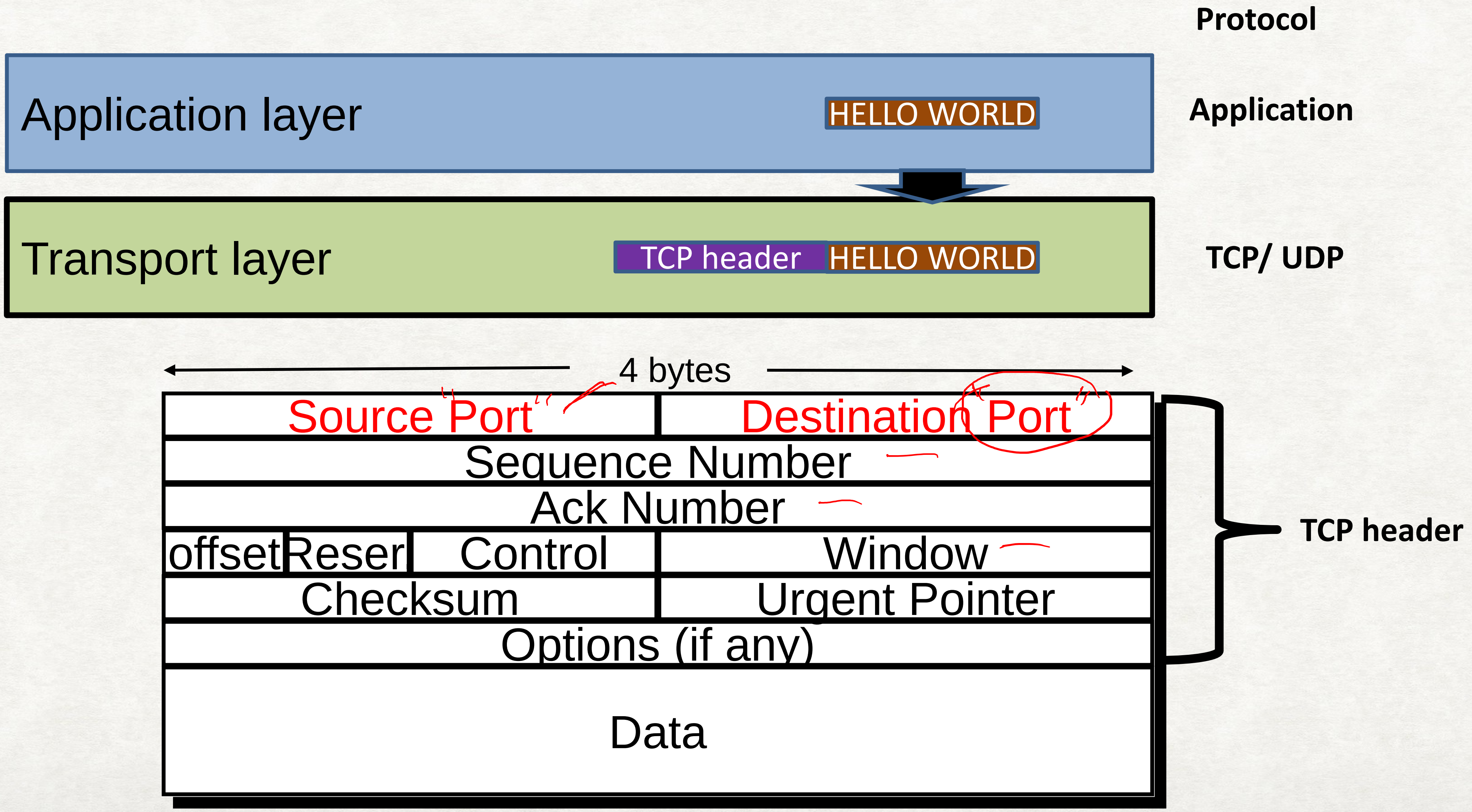
Application layer to Transport layer



The transport layer computes packet length and checksum.

Application layer to Transport layer

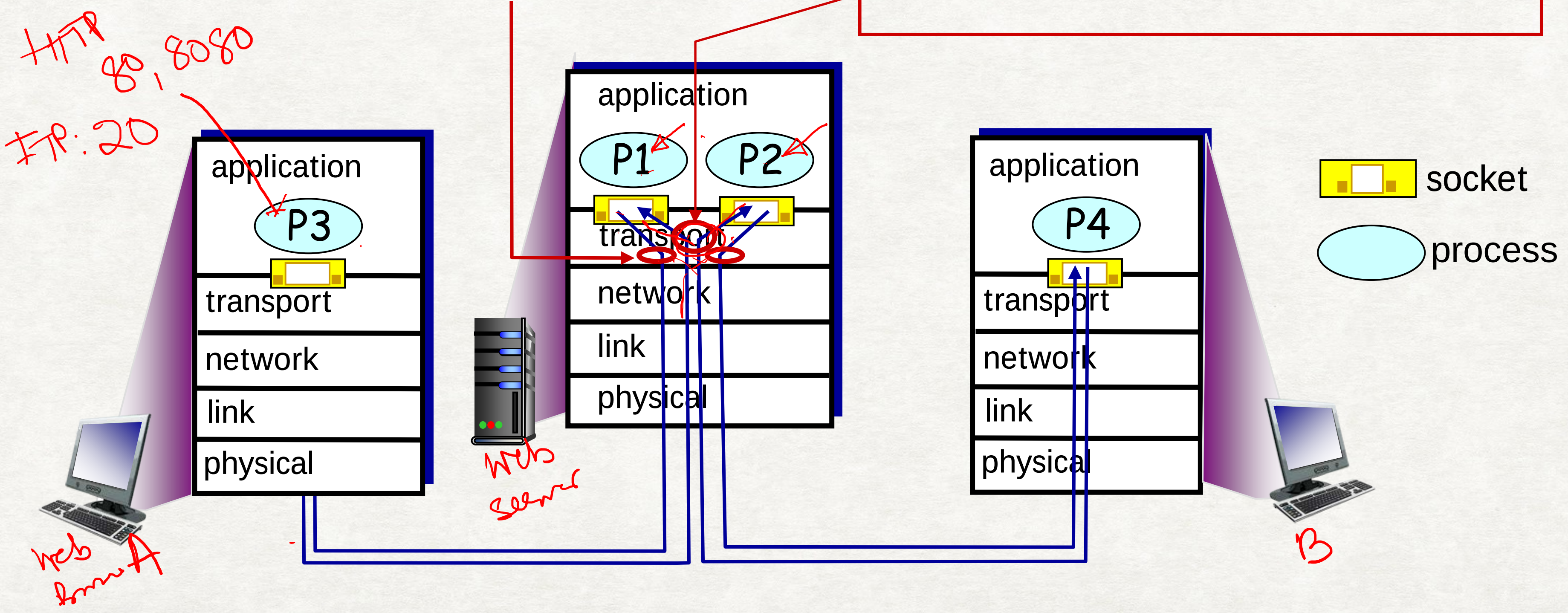




Multiplexing/demultiplexing using port numbers at the Transport Layer

multiplexing at sender:
handle data from multiple processes, add transport header

demultiplexing at receiver:
use header info to deliver received segments to correct socket



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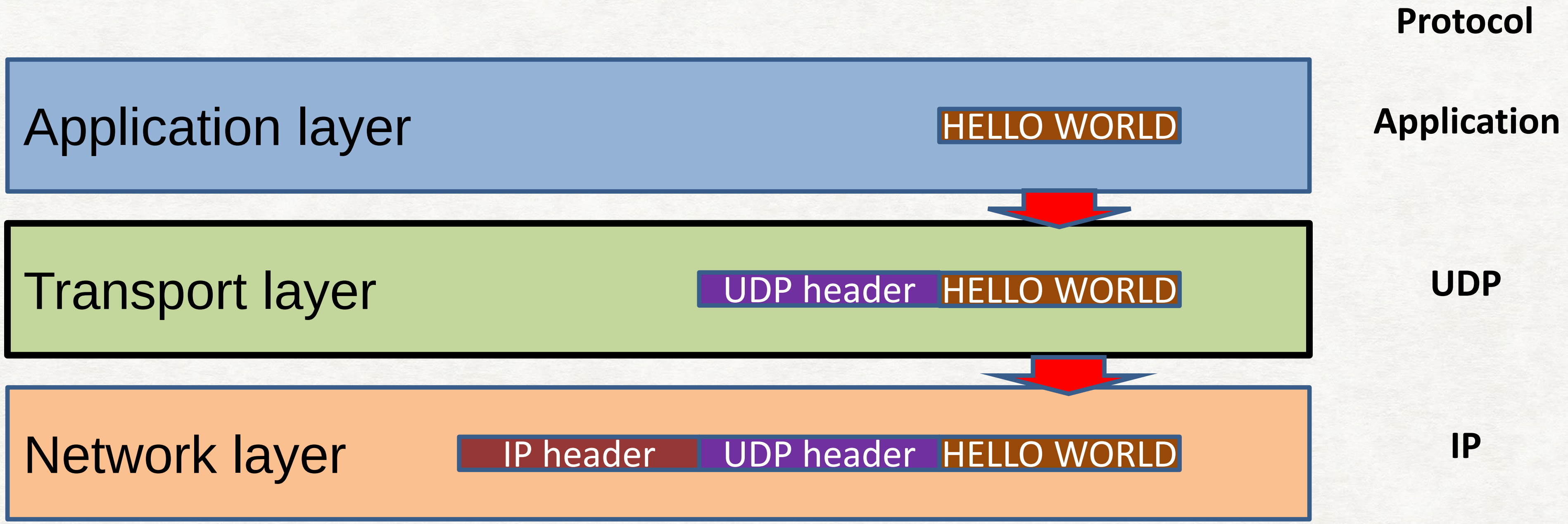
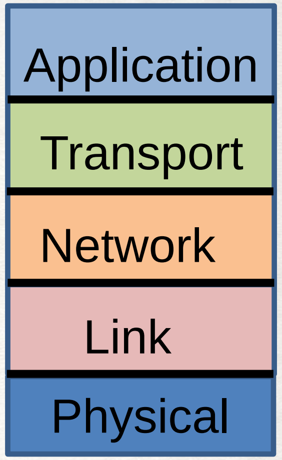
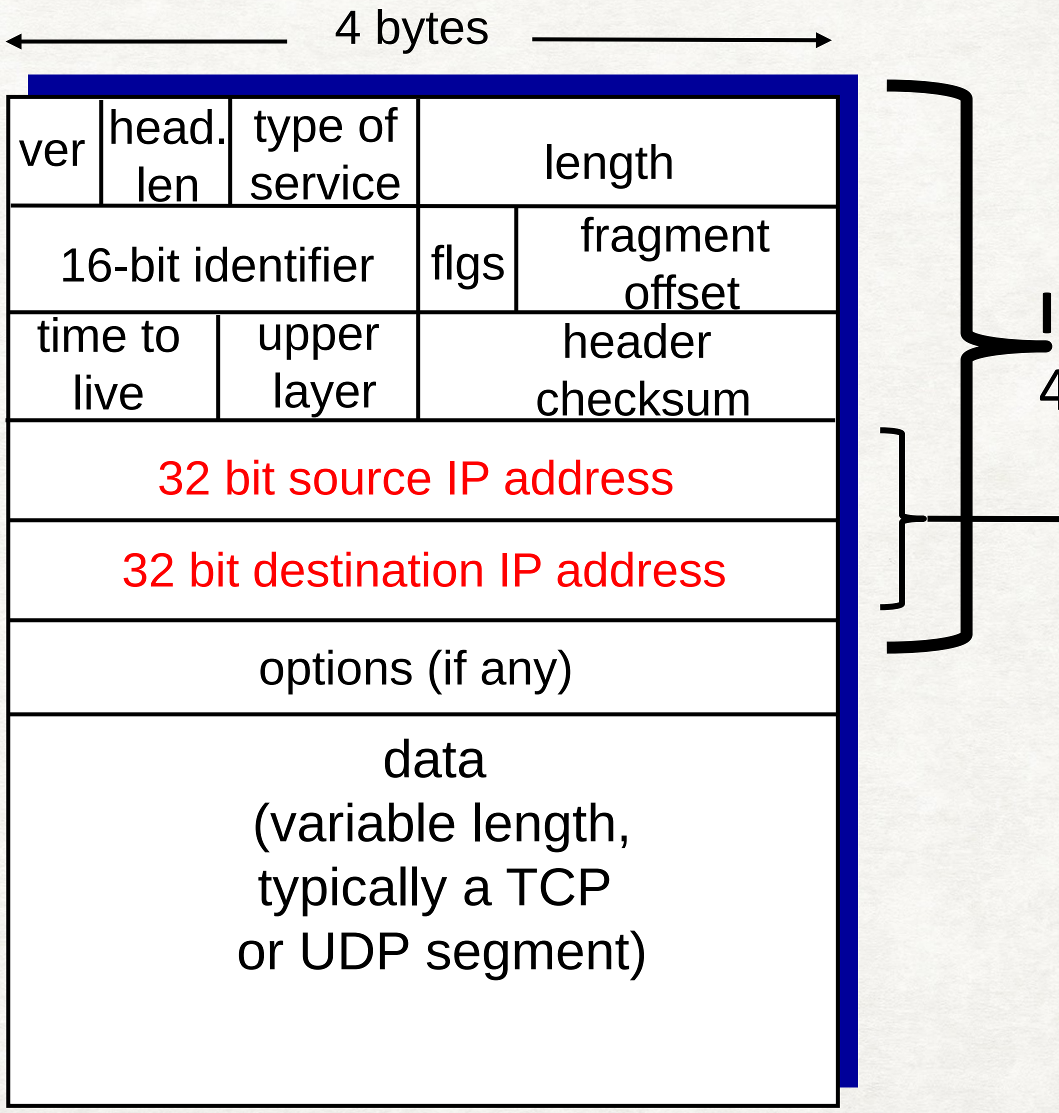
Application layer to network layer





Internet Protocol (IPv4) Header



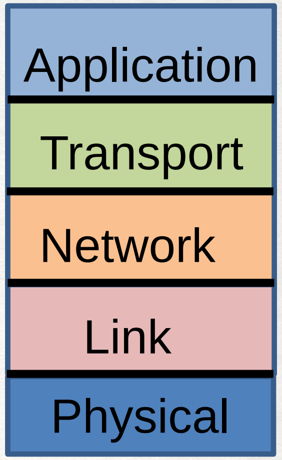
IP header
4*5 = 20 bytes

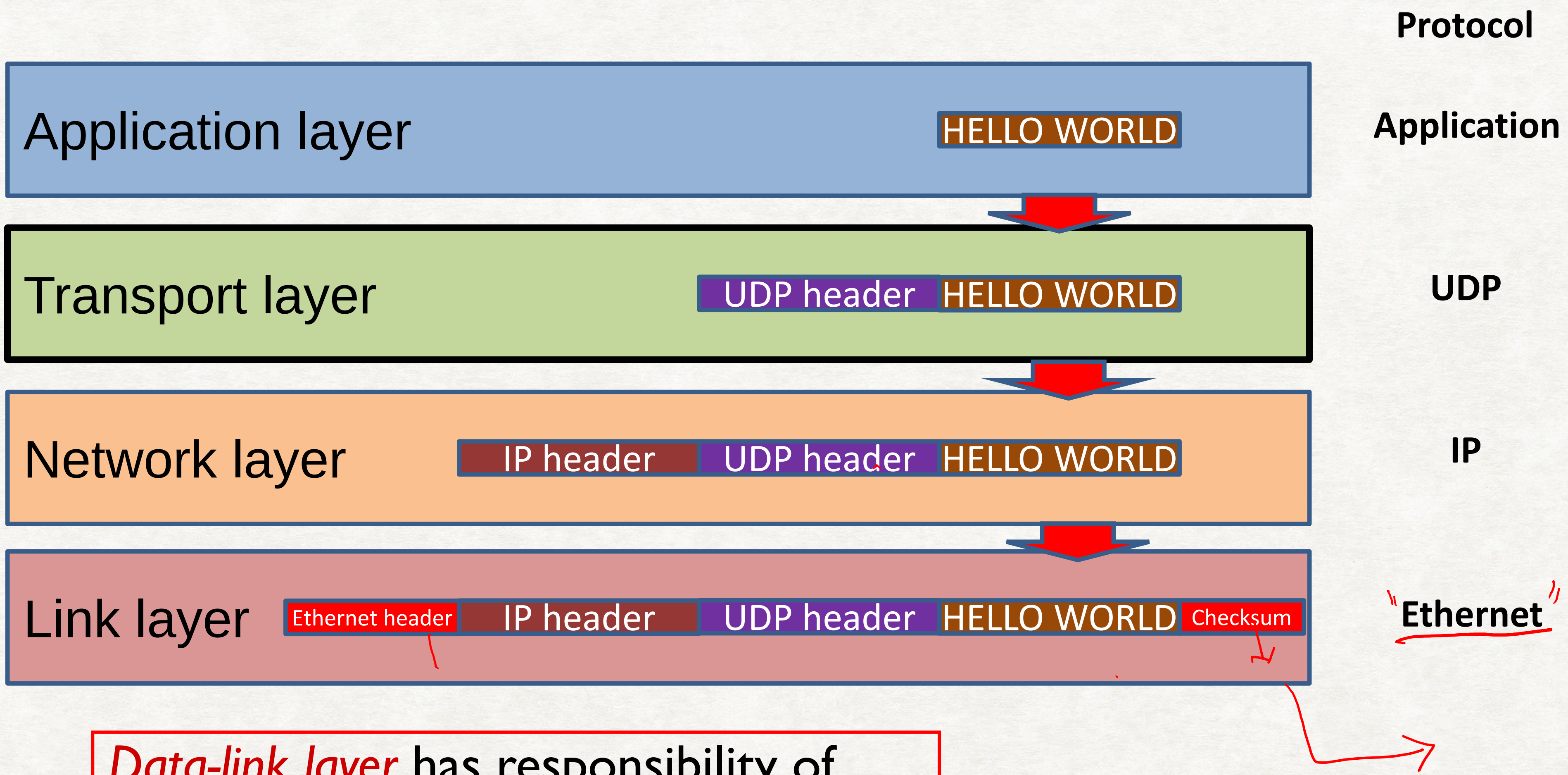
IP addresses: 32 bit

- **IPv4:** 4 byte addresses
  e.g. 172.88.205.9
- **IPv6:** 16 byte addresses 128-bits
  e.g., 2019:0FA3:0000:0000:49C3:0000:0000:0000
  (or 2019:0FA3:0:0:49C3:: in short)

Application
Transport
Network
Link
Physical

Application Layer to Data link layer





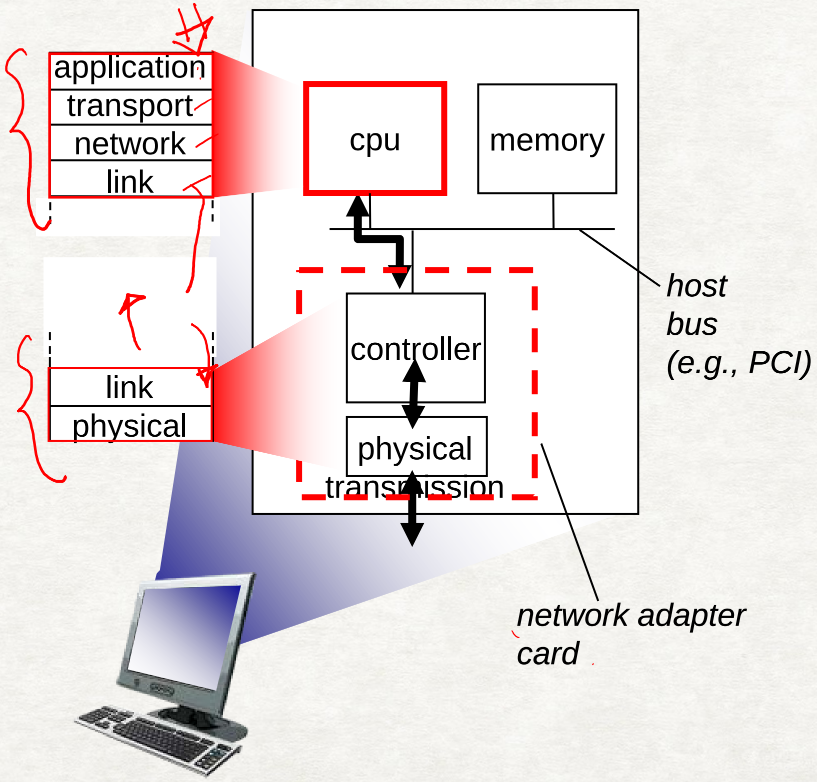
Data-link layer has responsibility of transferring datagram from one node to *physically adjacent* node over a link

Where is the link layer implemented?

Implemented in “adaptor” (aka *network interface card* NIC) or on a chip

Ethernet card, 802.11 card;

Combination of hardware, software, firmware.



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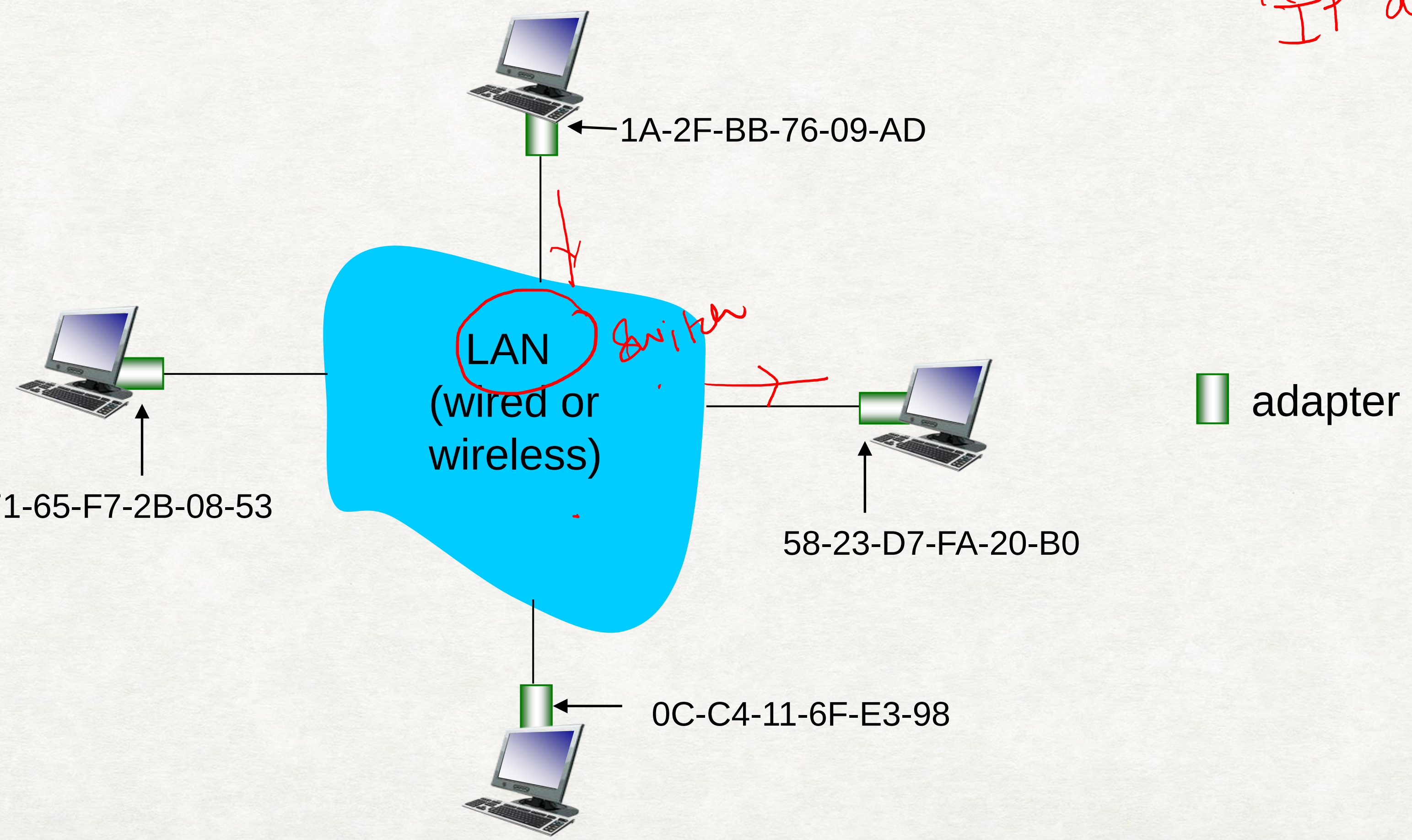
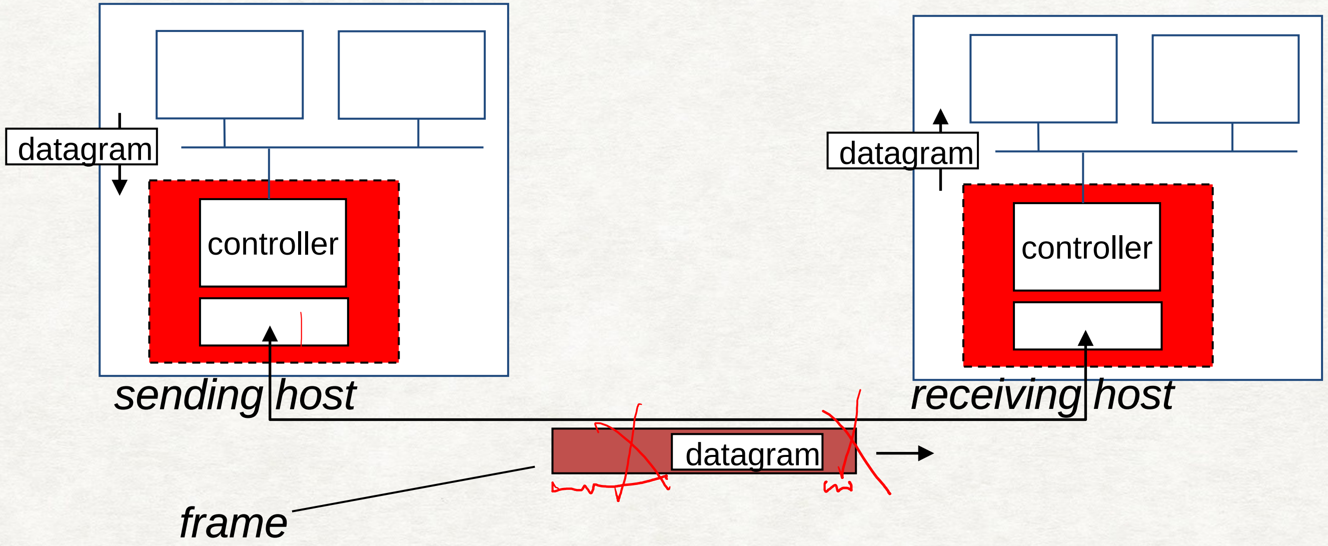
MAC addresses

Each adapter on LAN has unique "MAC" address

"IP addresses"



Adaptors communicating



❖sending side:

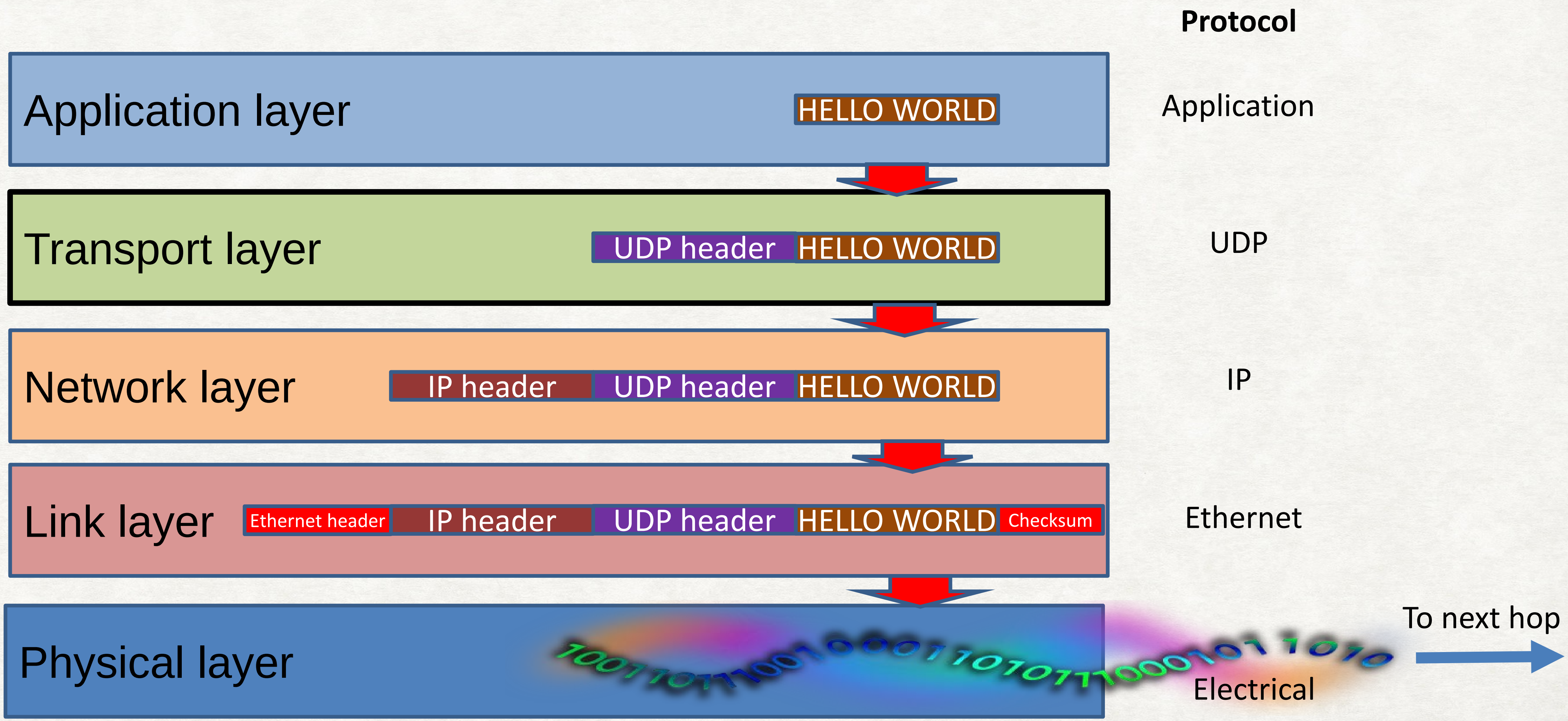
- encapsulates datagram in frame
- adds error checking bits, reliable delivery, flow control, etc.

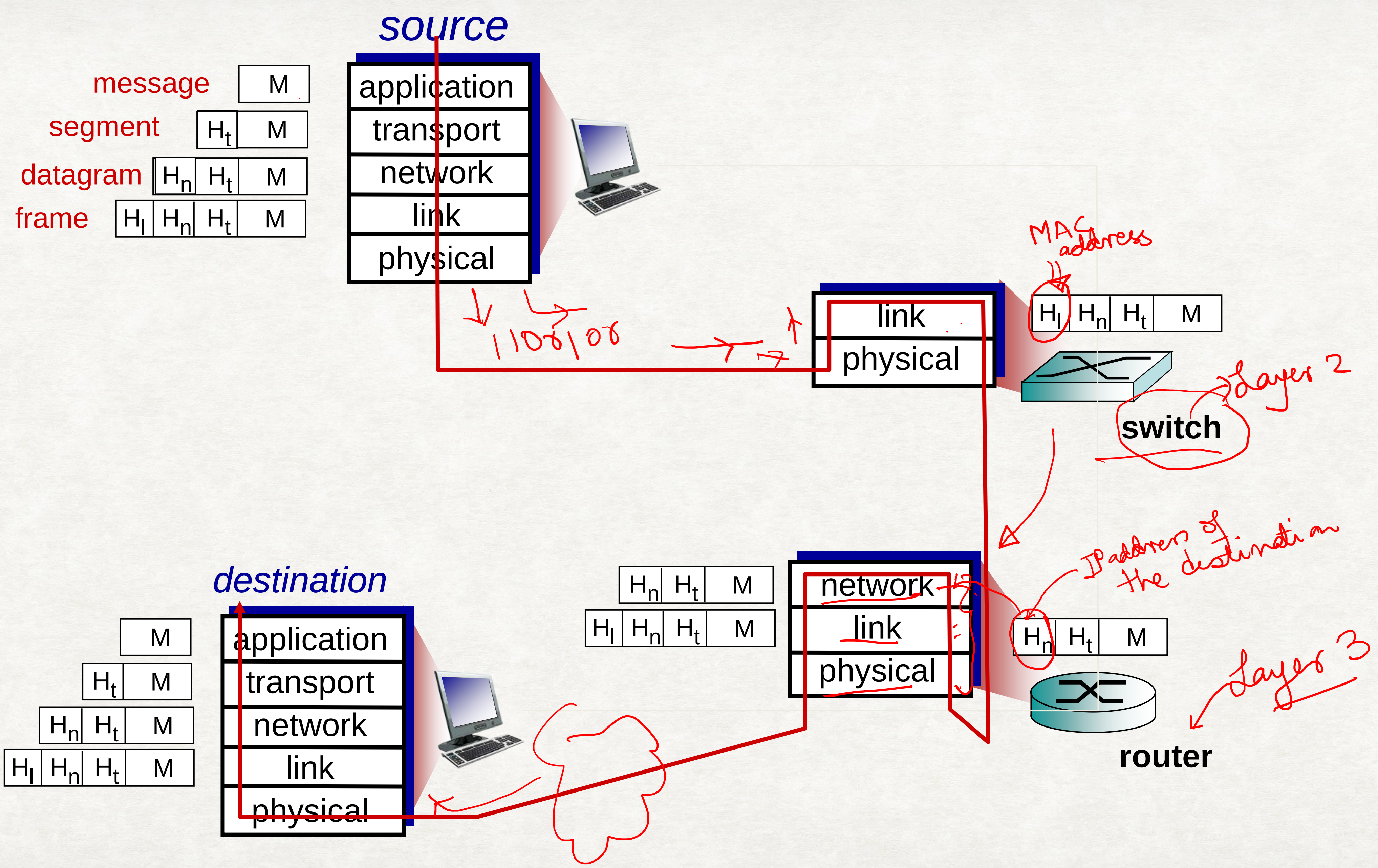
❖receiving side

- looks for errors, reliable delivery, flow control, etc
- extracts datagram, passes to upper layer at receiving side

Reference : *Computer Networking:A Top Down Approach by Kurose & Ross*

Packet's journey on the sending computer...





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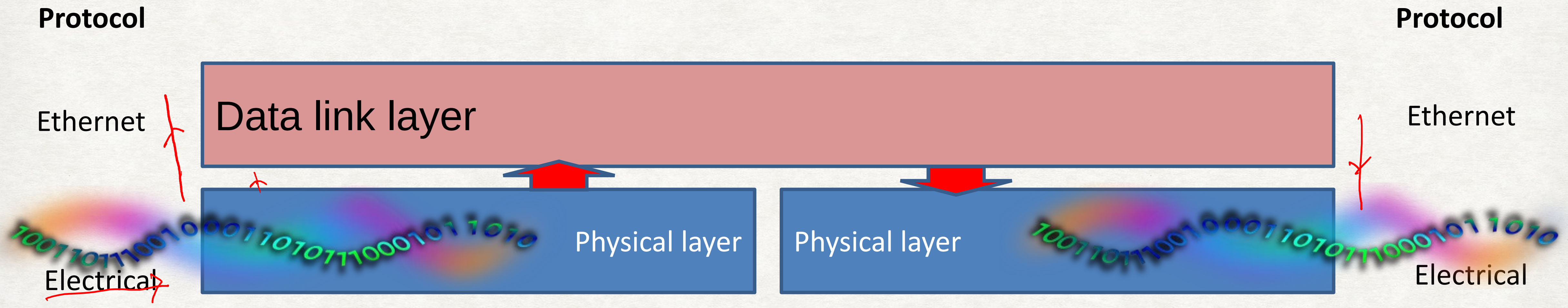
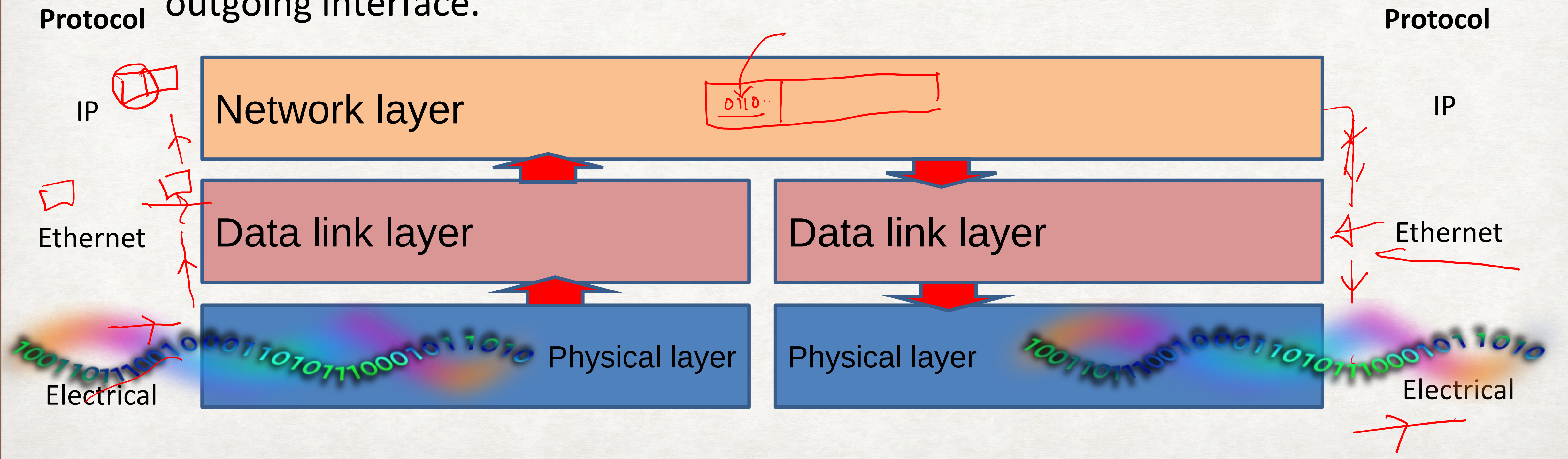
The next hop could be a switch

Ethernet packet is forwarded based on MAC address.
IP packet remains completely untouched.
Network layer is not involved.



At the next hop, there could be a router

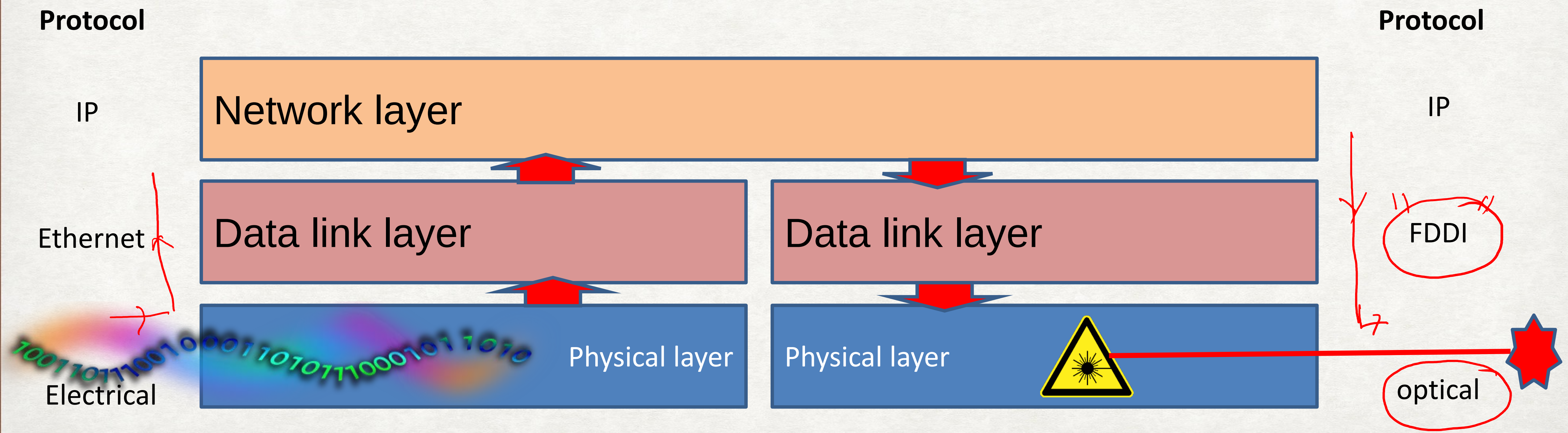
Packet is received by physical layer, de-encapsulated by data link layer.
IP packet is routed by the network layer. The network layer does not de-encapsulate the packet.
No layers above the network layer get involved.
IP packet is then encapsulated by outgoing data link layer and transmitted by outgoing interface.



One hop further

E.g., the next router could forward onto an optical fibre cable

- Packet is received by physical layer, de-encapsulated by data link layer.
- IP packet is routed by the network layer.
- IP packet is then encapsulated by outgoing data link layer and transmitted as light by the outgoing interface.

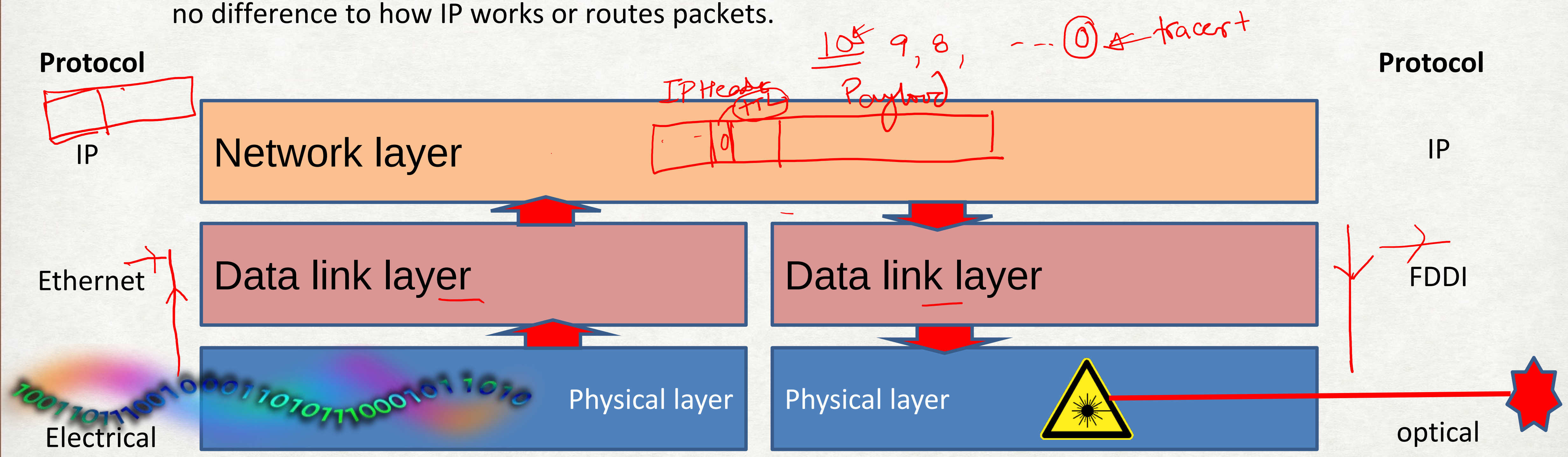


Routing notes

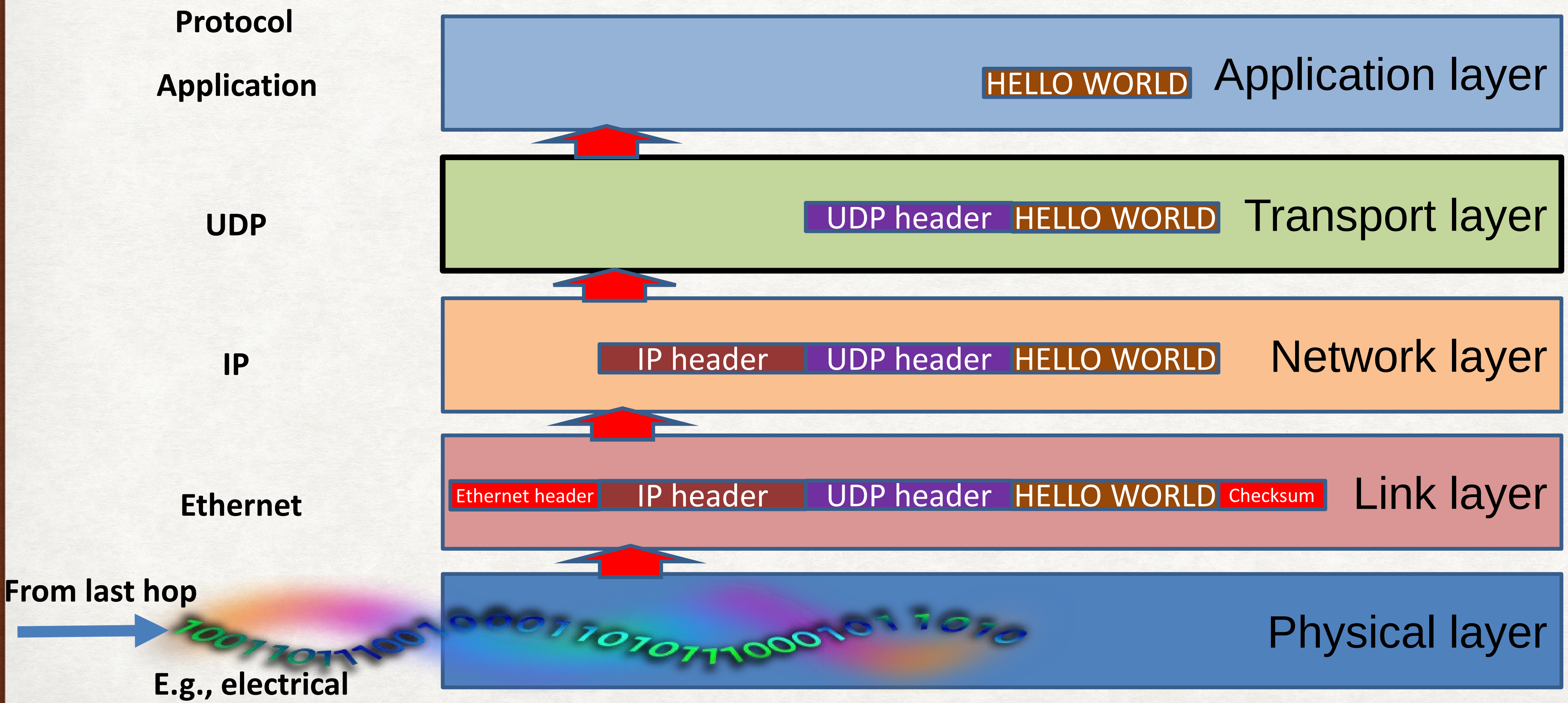
IP headers essentially don't change as they pass through routers

Strictly speaking, that's not true: The IP header contains a TTL (Time To Live) field that gets decremented at each router. When the TTL reaches 0, the router drops the packets. This prevents IP packets from living forever on the Internet, e.g., in cases of routing loops.

An IP packet may encounter many different data link layers and physical layers along its path, but this makes no difference to how IP works or routes packets.



Our packet's journey on the receiving computer



The real benefit of encapsulation – Flexibility!

We can use encapsulation to recursively layer protocols.

This is the mechanism used in a number of technologies in use on the Internet today.

1. IPv6/IPv4 interfaces.
2. Virtual Private Networks
3. Mobile Routing

Transition from IPv4 to IPv6

128

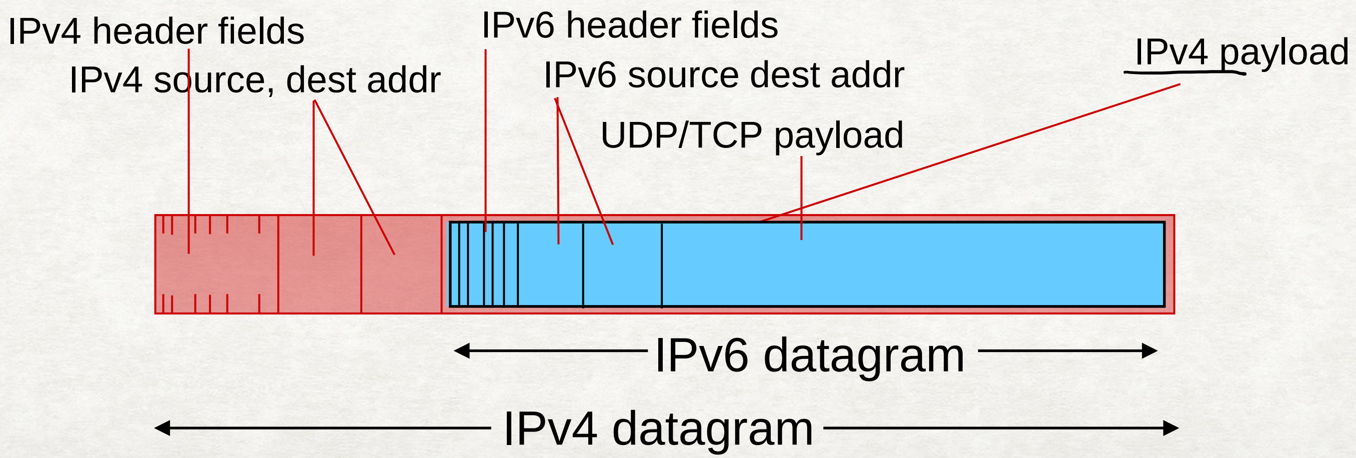
2^{32}

2^{128}

Not all routers can be upgraded simultaneously

No "flag days"
How will network operate with mixed ipv4 and ipv6 routers?

Tunneling: ipv6 datagram carried as *payload* in ipv4 datagram among ipv4 routers



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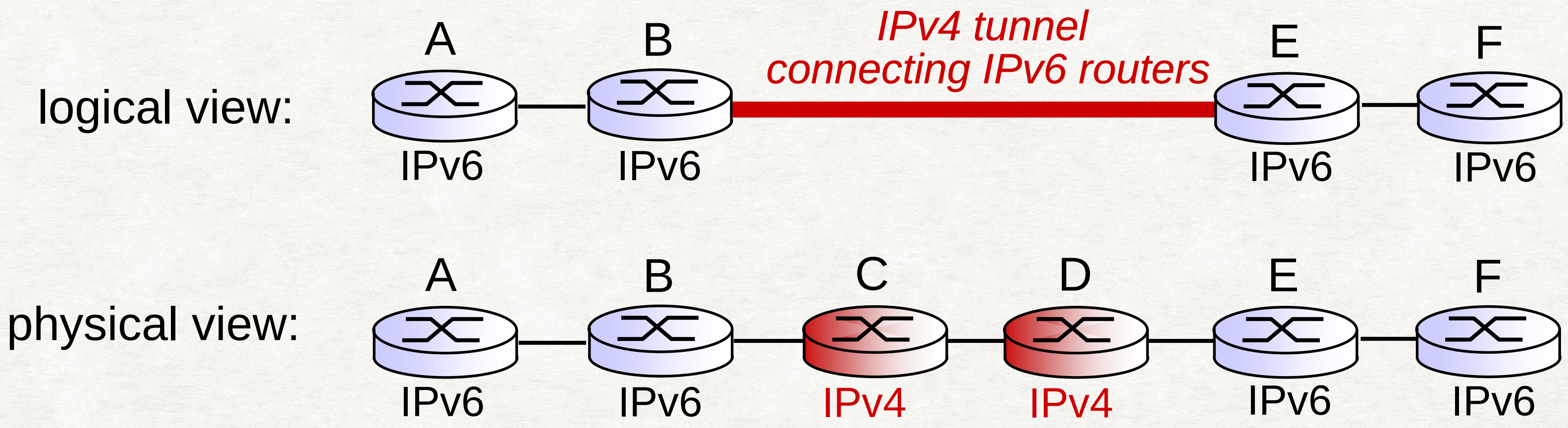
Tunneling



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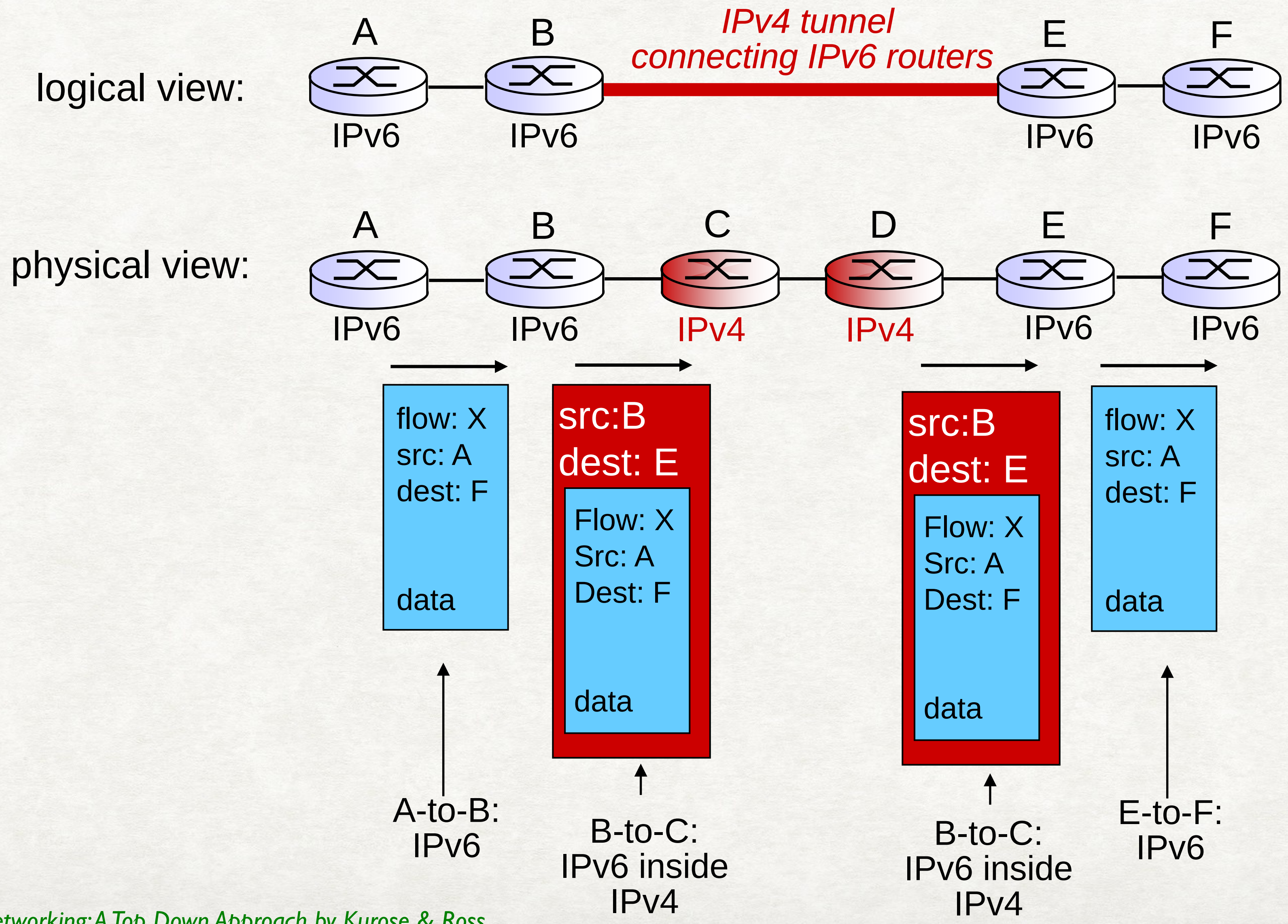
Tunneling



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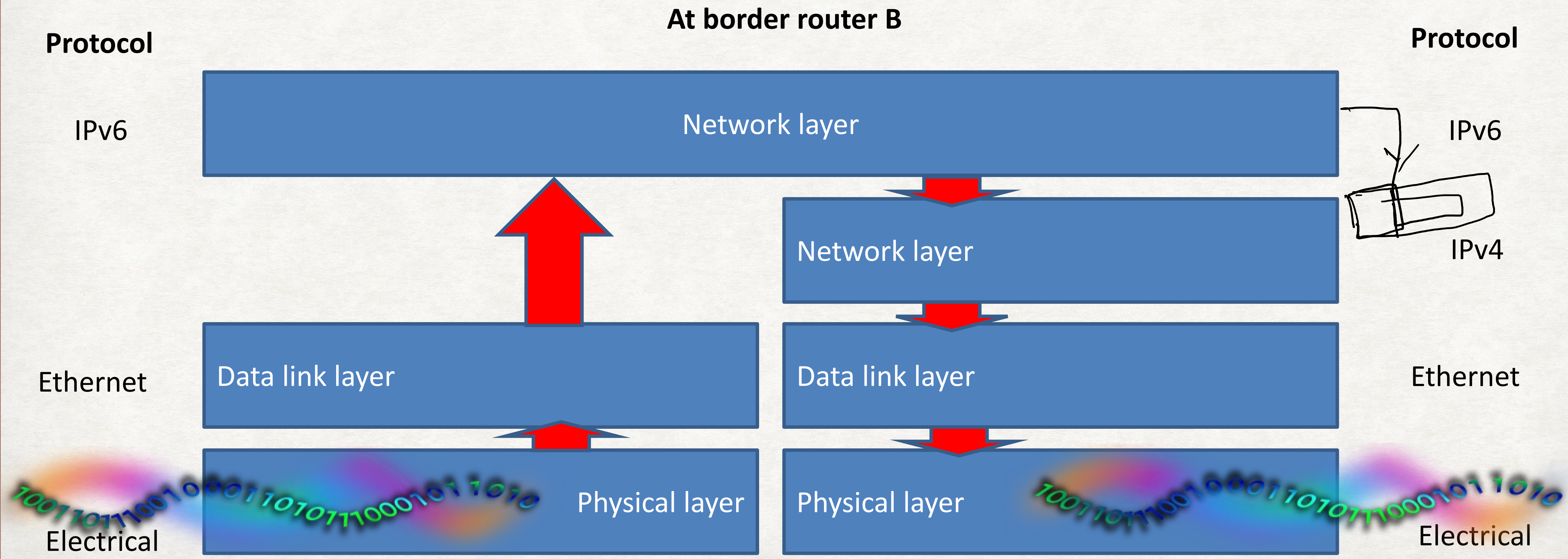
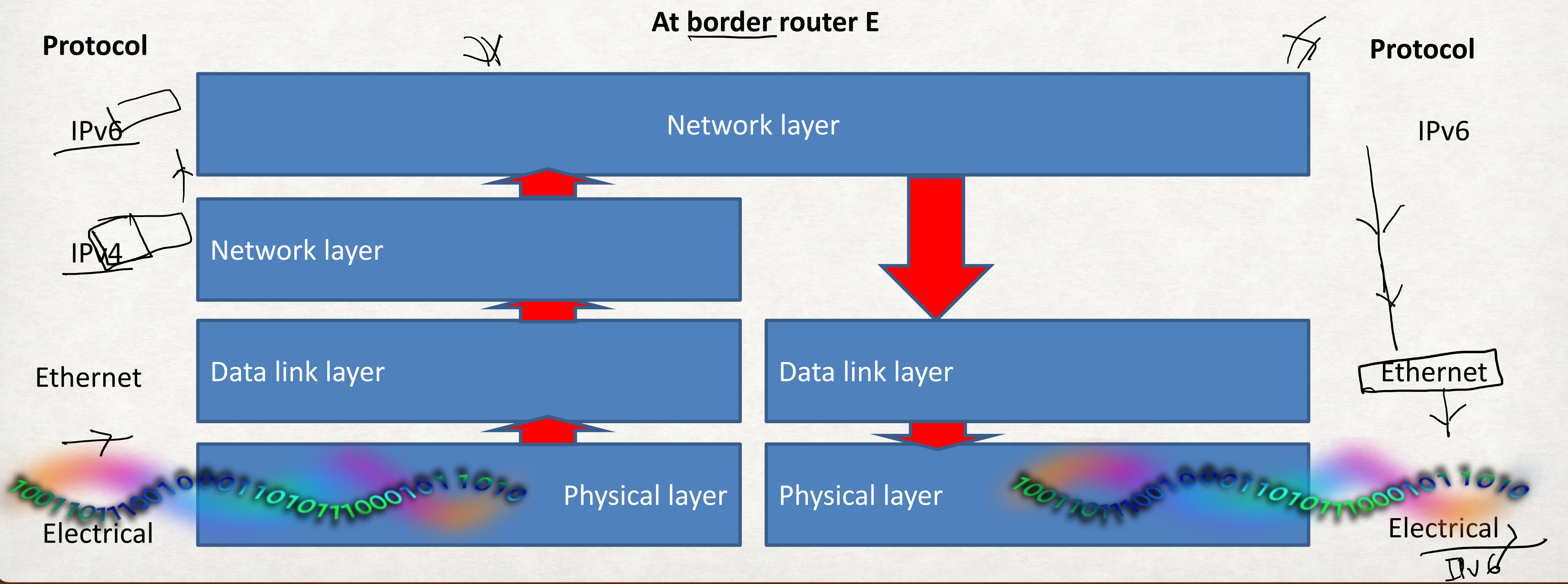
Router tunnelling IPv6 over IPv4

The tunnelling can be achieved by an extra network layer that uses IPv4



On the other side of the IPv4 tunnel

Received IPv4 packets get de-encapsulated to yield IPv6 packets
IPv6 continues as “normal”. IPv6 hosts never know about the IPv4 in the middle!



Notes and summary

- Digital communication systems are built on a system of *layers.*
- In their entirety, these layers are known as a (protocol) *stack*.
- Layers other than the physical layer are algorithms that carry out specific functions related to the communication protocol . such as UDP, TCP, IP, Ethernet, or a variety of other protocols.
- Layers encapsulate or de-encapsulate packets as part of their operation by adding or removing headers.
- At the sender, the data travels down the stack, at the receiver it travels up the stack. At intermediate routers and switches, the data travels part-way up the stack and then down again.
- Protocol stacks can be designed to be fit for purpose.